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memorandum

Advanced Fuel Cycle Initiative

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Subject: Gen IV Reactor Materials

Letter Report on Gen IV Reactor Materials:

The Generation IV Reactor Program proposes six innovative nuclear energy systems. These are a gas-cooled fast-reactor (GFR) system, a lead alloy-cooled reactor (Pb Alloy), a molten-salt reactor (MSR) system, a sodium liquid-metal-cooled reactor system (Na LMR), a supercritical water-cooled reactor (SCWR) system, and the very high temperature reactor (VHTR) system. All these systems pose unique conditions on reactor materials such as very high temperatures, very high doses, corrosive conditions, and high pressures. A high-temperature reactor materials workshop held in March 2002 proposed the principal structural materials for each of these reactor concepts [1]. In addition, a recent survey of materials needs was performed specifically for the VHTR reactor concept [2]. This letter report summarizes the materials needs for Gen IV reactor systems combined with those for the accelerator-driven system (ADS).

The expected operating temperature ranges for the Generation IV Reactor and the accelerator-driven systems are summarized in Table 1 from reference [1]. For such operating temperatures, a range of materials may be suitable for use as listed in Table 2. Many of these materials have not been tested under prototypic Generation IV Reactor or ADS conditions of proton/neutron spectrum and irradiation temperature. To test some of these prototypic conditions, specimens are being included in an irradiation campaign at the SINQ 590-MeV accelerator at the Paul Scherrer Institute called STIP (SINQ Target Irradiation Program). In addition, specimens previously irradiated at the Fast-Flux Test Facility will be tested. To test other materials and conditions, future irradiations will be needed at accelerators or fast reactors.

References:

1. Allen, T. *et al*., *Higher Temperature Reactor Materials Workshop,* ANL-02/12, Argonne National Laboratory, 2002, pp. 1-58.
2. Baccaglini, G. *et al*., *Very High Temperature Reactor (VHTR): Survey of Materials Research and Development Needs to support Early Deployment,* INEEL/EXT-03-00141, INEEL, 2003, pp. 1-52.

Distribution:
None

Table 1. Principal Primary Operating Temperature Ranges for Generation IV Reactor Concepts and Accelerator-Driven Systems

Low Temperature (<350ºC)
Integral Primary System Reactors Simplified BWR's Evolutionary Pressure Tube Reactors High-Conversion LWRs
Intermediate Temperatures (~350-600ºC)
Supercritical LWRs-Thermal and Fast Sodium-cooled LMRs Lead/Lead-Bismuth Cooled LMRs Accelerator Driven Systems (ADS)
Intermediate-to-High Temperatures (~600-900ºC)
Lead/Lead-Bismuth Cooled LMRs Molten Salt Fueled Reactors Prismatic Gas-Cooled Reactors Pebble Bed Gas-Cooled Reactors Gas-Cooled Fast Reactors
High Temperatures (>900ºC)
Very High Temperature Gas-Cooled Reactors Molten Salt Cooled Reactors Gas Fueled Reactors

Table 2. Potential Nuclear Applications for some Materials Systems

Alloy	Description	Potential Application
Austenitic Alloys		
316L and 304L stainless steels	316L has slightly more nickel than 304L, which adds some more stability to the austenite phase	Pb alloy, Na-LMR (metal and MOX)
F/M Alloys		
HT-9	12Cr-1MoVW	VHTR, ADS, Na-LMR (metal), SCWR-thermal, SCWR-Fast
Mod 9Cr-1Mo (T91)	Developed after HT-9 and has lower chrome to decrease formation of irradiation induced α'	VHTR, ADS, Na-LMR (metal), SCWR-thermal, SCWR-Fast
T91-TMT,	A thermo-mechanical treatment used to improve properties	VHTR, ADS, Na-LMR (metal), SCWR-thermal, SCWR-Fast
9Cr-2WVTa	A low activation T91 alloy in which Mo is replaced by V and Ta	VHTR, ADS, Na-LMR (metal), SCWR-thermal, SCWR-Fast

Alloy	Description	Potential Application
HCM12A (T122), HCM12, NF616 (T92). E911, A21 nitrogen modified 9Cr	Slight variations of T91 to improve properties	VHTR, ADS, Na-LMR (metal), SCWR-thermal, SCWR-Fast
F82H	~7.5Cr2W-Low activation alloy	VHTR, ADS, Na-LMR (metal), SCWR-thermal, SCWR-Fast
ODS Strengthened F/M alloys	Oxides added to improve high-temperature strength and creep resistance.	VHTR, ADS, Na-LMR (MOX), Na-LMR (metal), SCWR-thermal, SCWR-Fast
EP 823	Russian developed F/M steel with high Si	LBE target, Pb alloy
Refractory Metals		
Tantalum	High-density material with high ductility at room temperature	ADS target, LBE containment, Pb alloy reactor
Tungsten	High-density material with low ductility at room temperature	ADS target
Mo (TZM)	Machinable high-strength refractory alloy	MSR
Nb-1Zr		MSR
Nickel Superalloys		
Inconel 718, 800, 690, 625	Corrosion resistant with high-strength at high temperatures	ADS window, VHTR, GFR, SCWR-thermal, SCWR-Fast
INOR-8	High Mo Nickel based alloy	MSR, GFR
Ceramic/Ceramic Composites		
Graphite		VHTR, MSR
Carbon/Carbon Composites	High-strength composite material, low oxidation resistance, brittle	VHTR, GFR
SiC/SiC Composites	High-strength composite material, brittle	VHTR, GFR